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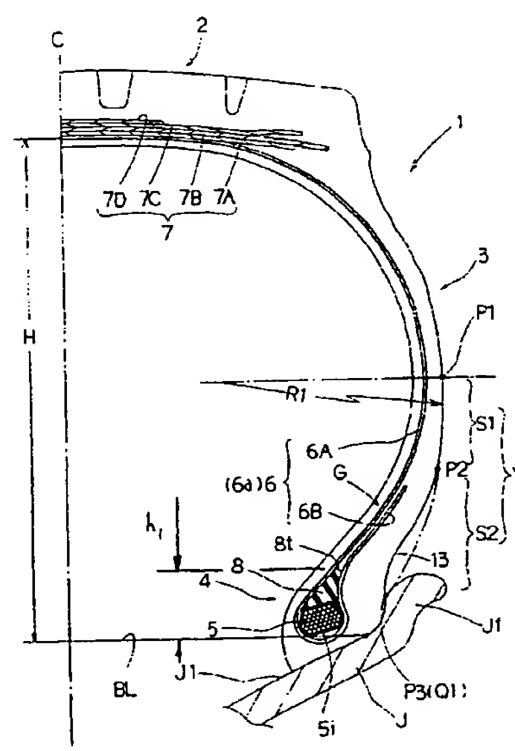
(54) Pneumatic tyre

(57) A pneumatic tyre has an outer surface provided with a mid-lower sidewall contour S1 and a lower sidewall contour S2, the contour S1 extends radially inwardly from the maximum cross sectional width point P1 of the tyre to a point P2 along a circular arc line E1 having a single radius R1 and the centre on an axial line passing the maximum cross sectional width point P1, the contour S2 extends on the axially inside of the circular arc line E1 from the point P2 to a radially inner point P3, the rubber thickness T measured from the tyre outer surface to the main portion (6A) of a carcass is gradually increased from the point P1 to the point P2. The bead portions (4) are provided between the carcass main portion (6A) and each tumup portion (6B) with a bead apex (8) made of hard rubber tapering radially outwardly to the radially outer end thereof, the carcass turnup portion (6B) extends radially outwardly beyond the radially outer end (8t) of the bead apex (8) to form a parallel part, the parallel part extending radially outwardly from the radially outer end of the bead apex substantially parallel to the carcass main portion (6A), and the length L of the parallel part is in the range of from 0.5 to 5.0 times the maximum-section-width CW of the bead core (5).

Fig.1



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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 0108

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	7 September 2000	Baradat, J-L

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X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 98 30 0108

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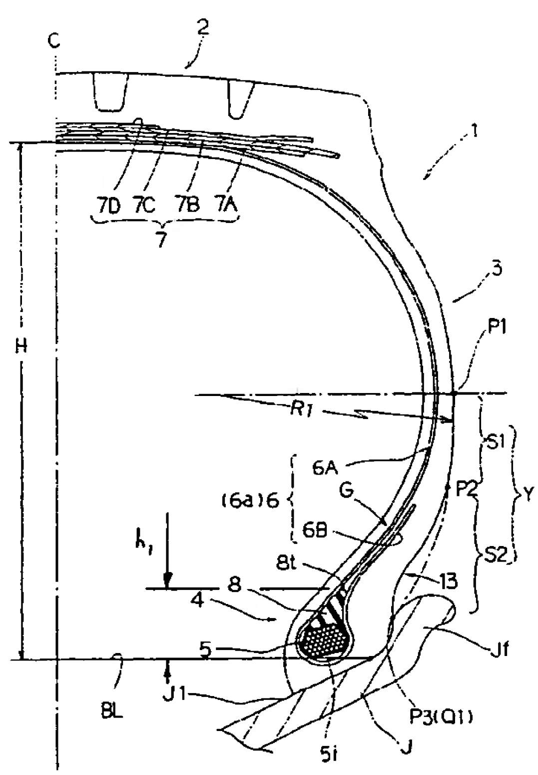
Fig.1



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Description

The present invention relates to a pneumatic tyre, more particularly to an improved bead and lower sidewall structure which is capable of improving the bead durability, tyre weight, crack resistance and the like and thus can be suitably employed in heavy-duty radial tyres.

In heavy duty radial tyres for trucks, buses and the like, in order to increase the durability of the bead portions, conventionally, reinforcing cord layers and a great volume of hard rubber are disposed in the bead portions as shown in Fig.7. However, in very severe service conditions under which such tyres are often used, the increased rubber volume increases heat generation, and bead durability is quickly lost. Further, the tyre weight is inevitably increased, as is the fuel consumption of the vehicle.

In Japanese Patent Publication No. JP-A-55-19685, a radial tyre is disclosed, wherein a lower sidewall region is profiled so as to increase the flexibility of the sidewall portions. If the teachings thereof are applied to a heavy duty tyre, as shown in Fig.12, the rubber thickness t1 is almost constant in a region y1 which region extends from the tyre maximum cross sectional width point P1 to a relatively low point P2, and from the point P2 the rubber thickness t2 abruptly increases. As a result, the rubber volume can be decreased. However, as the tyre surface changes from convex to concave at point P2, and the concave part y2 is positioned on the axially outer side of the convex surface line e1, the bending deformation during running is concentrated on the point P2, and bead durability is not good.

On the other hand, if the rubber volume is decreased, such a tyre would be increased in bending deformation in the lower sidewall region and upper bead region. As a result, the outer surface of the tyre is liable to crack in the regions, which may induce bead damage such as carcass ply looseness. Further, it is impossible to retread tyres the outer surface of which is cracked.

It is therefore, an object of the present invention to provide a pneumatic tyre which is improved in durability and tyre weight and overcomes the above problems.

According to one aspect of the present invention, a pneumatic tyre comprises a tread portion, a pair of sidewall portions, a pair of bead portions each with a bead core therein, a carcass extending between the bead portions and turned up around the bead cores from the inside to the outside of the tyre to form a pair of turnup portions and a main portion therebetween, wherein the outer surface of the tyre is provided with a mid-lower sidewall contour S1 and a lower sidewall contour S2, the mid-lower sidewall contour S1 extending radially inwardly from the maximum cross sectional width point P1 of the tyre to a point P2 along a circular arc line E1 having a centre on an axial line passing through the maximum cross sectional width point P1, the lower sidewall contour S2 extending on the axially inner side of the circular arc line E1 from the point P2 to a radially inner point P3, and the thickness T measured from the outer surface of the tyre to the main portion of the carcass is gradually increased from the point P1 to the point P2.

Preferably, the bead portions are provided between the carcass main portion and each turnup portion with a bead apex made of hard rubber tapering radially outwardly to the radially outer end thereof, and the turnup portion extends radially outwardly beyond the radially outer end of the bead apex to form a parallel part, the parallel part extending radially outwardly from the radially outer end of the bead apex substantially parallel to the carcass main portion, and the length L of the parallel part is in the range of from 0.5 to 5.0 times the maximum-section-width CW of the bead core.

Embodiments of the present invention will now be described in detail in conjunction with the accompanying drawings.

Fig.1 is a cross sectional view of an embodiment of the present invention mounted on a rim;
Fig.2 is an enlarged sectional view showing the bead and lower sidewall structure of the tyre of Fig. 1;
Fig.3 is a schematic cross sectional view showing a cushion rubber layer between the carcass ply turnup portion and main portion;
Figs.4(A) and (B) are schematic cross sectional views for explaining the contour of the bead and sidewall lower portion;
Fig.5 is a cross sectional view showing a decorative rib on the sidewall;
Fig.6 is a cross sectional view showing another example of the bead and lower sidewall structure;
Fig.7 is a cross sectional view showing a prior art construction;
Fig.8 is a graph showing the results of a test for principal strain;
Figs.9 and 10 are diagrams for explaining a method of measuring the principal strain;
Fig.11 is a cross schematic sectional view of the bead and lower sidewall structure of a test tyre according to the invention; and
Fig.12 is a cross schematic sectional view of the bead and lower sidewall structure of a test tyre according to the prior art.

In the drawings, the tyre 1 according to the present invention comprises a tread portion 2, a pair of axially spaced bead portions 4 each with a bead core 5 therein, a pair of sidewall portions 3 extending between the tread edges and

the bead portions, a carcass 6 extending between the bead portions 4, and a belt 7 disposed radially outside the carcass 6 in the tread portion 2.

Fig.1 shows a meridian section of the tyre under the standard condition in which the tyre is mounted on a standard rim J and inflated to standard pressure and with no tyre load. The standard rim is the rim specified as standard rim or measuring rim in the well known standards, such as JATMA (Japan and Asia), T&RA (North America), ETRTO (Europe), STRO (Scandinavia) and the like, and the standard pressure is the maximum pressure specified in the standard.

The tyre 1 is a tube-less heavy-duty radial tyre for trucks and buses, and is mounted on a 15 deg. taper rim.

The above-mentioned carcass 6 comprises at least one ply 6A of cords arranged radially at an angle of from 70 to 90 degrees with respect to the tyre equator C, and extending between the bead portions 4 through the tread portion 2 and the sidewall portions 3, and turned up around the bead cores 5 from the axially inside to outside of the tyre, so as to form a pair of turnup portions 6B and a main portion 6A therebetween. For the carcass cords, preferably, steel cords are used, but organic fibre cords, e.g. polyester, rayon, nylon, aromatic polyamide and the like can be used. In this example, the carcass 6 is composed of a single ply 6A of steel cords arranged at substantially 90 degrees with respect to the tyre equator C.

The belt 7 comprises at least two crossed plies. For the belt cords, steel cords, organic fibre cords, e.g. nylon, aromatic polyamide, rayon, nylon and the like can be used. In this example, the belt 7 is composed of four plies; a radially innermost ply 7A made of parallel steel cords laid at a predetermined angle of 50 to 70 degrees with respect to the tyre equator C; and radially outer plies 7B, 7C and 7D made of parallel steel cords laid at angles of not more than 30 degrees with respect to the tyre equator C.

Each of the bead portions 4 is provided with a bead apex 8 made of a hard rubber compound. The bead apex 8 is disposed between the carcass ply main portion 6A and turnup portion 6B, and tapers radially outwardly from the bead core 5. Preferably, the bead apex 8 has a JIS A hardness of 60 to 99 degrees, more preferably 70 to 95 degrees.

Under the above-mentioned standard condition, the bead apex height h1 is in the range of from 6 to 31%, preferably 8 to 22 %, more preferably 8 to 14% of the carcass height H. (in Fig.2 about 11%)

The bead apex height h1 is measured radially between the radially outer end of the bead apex and the bead base line BL. The carcass height H is measured radially between the thickness centre line of the carcass and the bead base line BL along the tyre equator C. Incidentally, the bead base line BL corresponds with the rim diameter of the standard rim.

The axially inner surface of the bead apex 8, which contacts with the carcass main portion 6A, is defined by a substantially straight line, but the axially outer surface is defined by a concave line. As a result, the axially outward displacement of the carcass 6 when the tyre is loaded is controlled.

The bead core 5 in this example is formed in a hexagonal cross sectional shape by winding a steel wire, and the outside thereof is coated with rubber. Aside from steel wire, high modulus organic cords, e.g. aromatic polyamide and the like may be used. A radially inner side 5i of the hexagon is longest and inclined at substantially 15 degrees to the axial direction corresponding to the inclination of the tapered bead seat J1 of the rim J. The maximum-section-width CW of the bead core 5 lies in a direction substantially parallel to the bead bottom line.

As for the carcass 6, in order to minimise stress concentration on the turnup end, the turnup portion 6B is extended radially outwardly to a position at a predetermined height Hb which position is radially outward of the outer end 8t of the bead apex 8 but radially inward of the maximum width point P1 of the tyre. The height Hb measured from the bead base line BL is preferably set in the range of from 15 to 50 %, more preferably 20 to 40 % of the carcass height H. (in this example 29%)

The carcass turnup portion 6B extends radially outwardly from the axially outer extreme end of the bead core to the radially outer end of the bead apex 8 along the axially outer concave surface of the bead apex 8, and then extends substantially in parallel with the carcass main portion 6A, on the radially outside of the bead apex 8. The length L of this parallel part G is in the range of from 0.5 to 5.0 times, preferably 1.0 to 4.0 times, more preferably 2.0 to 4.0 times the maximum-section-width CW of the bead core 5. (in this example about 2.6 times)

In the parallel part G, as shown in Fig.3, the cord spacing N between the axially adjacent carcass main portion 6A and turnup portion 6B is set in the range of from 1.0 to 4.5 times, preferably 1.5 to 3.5 times the diameter D of the carcass cords 11. That is, a rubber layer whose minimum thickness corresponds to the cord spacing N exists between the carcass main portion 6A and turnup portion 6B, whereby the share therebetween can be effectively mitigated. If the cord spacing N is less than 1.0 times the diameter D, the mitigation becomes insufficient, and sometimes the cords of the turnup portion 6B partially come into direct contact with those of the main portion 6A which causes carcass cord looseness. In this example, a separate rubber layer 12 called cushion rubber having elastic characteristics similar to the topping rubber for the carcass ply is disposed between the main portion 6A and turnup portion 6B. However, it is also possible to use the topping rubber itself as a substitute for the cushion rubber layer 12 if the required uniform thickness is provided. When the carcass 6 is composed of two or more plies, it is necessary that at least one ply has the above-explained parallel part G.

In the meridian section of the tyre under the above-mentioned standard condition, to effectively reduce the tyre

weight without deteriorating durability, the tyre is provided in a region Y which is radially inward of the maximum cross-sectional width pint P1 with a mid-lower sidewall contour S1 and a lower sidewall contour S2.

The mid-lower sidewall contour S1 extends from the maximum width point P1 to a radially inner point P2 along a circular arc E1 of a single radius R1 the centre of which is positioned on an axial line passing through the maximum width points P1. Thus the mid-lower sidewall contour S1 is convex.

The lower sidewall contour S2 is defined as extending on the axially inside of the circular arc line E1. The lower sidewall contour S2 is usually composed of a transitional convex upper contour 14 and a concave lower contour 13.

The convex upper contour 14 extends along a convex curved line, which is preferably a circular arc having a radius R2 in the range of from 0.2 to 0.4 times the radius R1. The convex upper contour 14 is connected to the mid-lower sidewall contour S1 at a point P2 without any infecting point.

The concave lower contour 13 extends along a concave curved line E2, which is preferably a circular arc having a single radius R3 in the range of not more than 0.95 times the radius R2. The concave lower contour 13 is connected to the convex upper contour 14 without any infecting point.

Figs.4(A) and (B) show two possible cases of the position (point P3) of the radially inner end of the lower sidewall contour S2.

In case of Fig.4(A), the lower sidewall contour S2 does not intersect the circular arc line E1, and contacts with the rim flange Jf at a point Q1 (hereinafter contact point Q1). Thus the point P3 is this contact point Q1.

In case of Fig.4(B), the lower sidewall contour S2 intersects the circular arc line E1 at point Q2.

Thus the point P3 is this intersecting point Q2. In this case, the radial distance WQ between the intersecting point Q2 and the contact point Q1 is set to be not more than 0.1 times, preferably not more than 0.05 times the height Hp1 of the maximum width point P1. If more than 0.1 times, the heat generation increases and the durability decreases.

Further, in order to further decrease the heat generation, the point Pm of the maximum depression Dm of the lower sidewall contour S2 from the circular arc line E1 is set at a radial height Hpm in the range of from 6 to 20 %, preferably 9 to 20 %, more preferably 12 to 18 % of the tyre section height H, and the maximum depression Dm is set in the range of from 0.03 to 0.18 times the height Hp1 of the maximum width point P1. Preferably, 0.05 =< Dm/Hp1. Preferably Dm/Hp1 =< 0.08, more preferably Dm/Hp1 =< 0.07. Usually, the maximum depression (Dm) is 3 to 6 mm. If Dm/Hp1 < 0.03, heat generation increases. If 0.18 < Dm/Hp1, it is difficult to set (T2/T1)/h1 and (Tm/T2)/h3 in the above-mentioned ranges. Further, deformation increases between the points P1 and Pm and cord loose becomes liable to occur.

The radial distance h2 between the points P2 and P3 is in the range of from 0.2 to 0.7 times the height Hp1. Preferably 0.3 =< h2/Hp1. Preferably h2/Hp1 =< 0.6. If h2/Hp1 < 0.2, the reduction in heat generation becomes insufficient, and further, the deformation is liable to concentrate on a position near the point Pm of the maximum depression Dm. If 0.7 < h2/Hp1, deformation decreases in the mid-lower sidewall region (S1), but increases in the sidewall lower region (S2) especially between the points P2 and Pm. Thus it becomes impossible to disperse the deformation widely and uniformly.

The thickness T between the outer surface of the tyre and the outside of the axially outermost carcass ply main portion 6A gradually increases from the maximum width point P1 to the point P3 to disperse strain widely and uniformly. However, it is not always necessary to increase the thickness T towards the radially inside in the region between the points P2 and Pm and/or the region between the points Pm and P3.

The thickness T1 at the maximum width point P1, the thickness T2 at the mid point P2, and the radial distance h1 between the points P1 and P2 are set as follows:

(T2/T1)/h1 is not less than 0.03, more preferably not less than 0.5; and
(T2/T1)/h1 is not more than 1.0, more preferably not more than 0.07.

If (T2/T1)/h1 < 0.03, bending deformation concentrates on the sidewall lower region (S2), and carcass cord loose is liable to occur.

In order to provide the necessary strength for the sidewall portions 3, the thickness T1 must be not less than 3 mm.

The thickness T2 at the point P2, the thickness Tm at the point Pm, and the radial distance h3 between the points P2 and Pm are set as follows:

(Tm/T2)/h3 is not less than 0.03, more preferably not less than 0.05; and
(Tm/T2)/h3 is not more than 0.25, more preferably not more than 0.15.

If (Tm/T2)/h3 < 0.03, bending deformation concentrates on a portion near the point Pm. If 0.25 < (Tm/T2)/h3, heat generation increases around the point Pm, and the tyre weight increases. Further, bending deformation is liable to concentrate on a portion near the point P2 and the durability decreases.

The thickness Tm at the point Pm, the thickness T3 at the point P3, and the radial distance h4 between the points Pm and P3 are set as follows:

(T3/Tm)/h4 is not less than 0.03, preferably not less than 0.05, more preferably not less than 0.07.

If (T3/Tm)/h4 < 0.03, bending deformation is liable to concentrate on a portion near the point P3 and carcass cord loose is liable to occur.

The above-mentioned radius R1 of the circular arc E1 is preferably set in the range of from 0.3 to 2.0 times the carcass height Ha. If R1/Ha < 0.3, it is difficult to maintain the necessary thickness T in the mid-lower sidewall region (S1). Also it is difficult to gradually increase the thickness T towards the radially inside. If 2.0 < R1/Ha, the thickness T excessively increases in the sidewall lower region (S2) and heat generation increases.

Further, in order to reduce the strain around the point Pm, the radially outer end of the carcass ply turnup portion 6B is extended radially outwardly beyond the point Pm, and the radial height difference therebetween is not less than 5 mm, preferably not less than 10 mm. In case a plurality of carcass plies are disposed, it is sufficient for this purpose that at least one carcass ply satisfies these conditions.

The present invention does not hinder provision of embossed marks, decorative rib and the like in the region Y on the sidewall. Fig.5 shows such a decorative rib 15. In such a case, it is possible to terminate the turnup portion 6B within the width wb of the rib 15 because it is desirable that the rubber thickness tb from the turnup end to the tyre outer surface is not less than 6 mm preferably not less than 9 mm. Preferably, the width Wb is set in the range of not more than 10 mm, and the protrusion hb of the decorative rib 15 from the tyre outer surface is in the range of not more than 3 mm to prevent strain concentration.

Fig.8 shows the maximum principal strain ε of three types of tyres: tyre A shown in Fig.1 having the parallel part G and the contours S1 and S2; tyre B shown in Fig.6 having the parallel part G only; and tyre C shown in Fig. 7 having neither the parallel part G nor the contours S1 and S2. In tyre C, a peak Z of principal strain (7 or 8%) appeared in the region Y. In tyres A and B, however, such a remarkable peak disappeared and the principal strain was decreased to an almost uniform value of less than 4.0 %. Thus, the sidewall portion 3 and bead portion 4 were effectively prevented from being cracked to improve durability.

If the length L of the parallel part G is less than 0.5 times the maximum-section-width CW of the bead core 5, a peak of principal strain ε appears in the region Y, and cracks are liable to occur in the peak position. If the length L is more than 5.0 times CW, the carcass turnup end reaches to the maximum width portion of the tyre where the bending deformation is largest, and problems of ply edge loose and decrease in the bead durability arise. If the cord spacing N is more than 4.5 times the diameter D, a peak of principal strain C appears in the region Y, and the heat generation is liable to increase.

The principal strain E was obtained as follows: (1) buff the surface of the sidewall portion 3 and bead portion 4; (2) wash the surface with naphtha; (3) apply adhesive agent to the surface; (4) inflate the tyre to a pressure of 0.5 kgf/sq.cm; (5) draw a radially extending strait line RL and copy a series of circles M from a vinyl tape 15 to the surface along the line RL as shown in Fig.9 wherein the circles are printed in white ink (titanium oxide+DOP+castor oil) using a printing screen; (6) inflate the tyre to the standard pressure; (7) copy the circles from the tyre surface to a new blank tape; (8) measure the circles on the tapes (under the standard pressure and 0.5kgf/sq.cm) for the abscissa values and ordinate values shown in Fig.10; and (9) compute the principal strain C using the following equations.

$$\text{Principal strain } \varepsilon = \frac{\varepsilon_c + \varepsilon_r}{2} + \frac{\sqrt{(\varepsilon_c + \varepsilon_r)^2 + r^2}}{2}$$

$$\text{Circumferential strain } \varepsilon c = \frac{Lc1 - Lc0}{Lc0}$$

$$\text{Radial strain } \varepsilon r = \frac{Lr1 - Lr0}{Lr0}$$

$$\text{Sharing strain } \gamma = \varepsilon c + \varepsilon r \times 2X\varepsilon_{195}$$

$$\text{135 degree direction } \varepsilon_{135} = \frac{L_{135}1 - L_{135}0}{L_{135}0}$$

Under 0.5 kgf/sq.cm pressure

$$\text{Circumferential length } Lc0 = \sqrt{(X10 - X20)^2 + (Y10 - Y20)^2}$$

$$\text{Radial length } Lr0 = \sqrt{(X30-X40)^2 + (Y30-Y40)^2}$$

$$\text{135 degrees direction length } L_{135}0 = \sqrt{(X50-X60)^2 + (Y50-Y60)^2}$$

Under the standard pressure

$$\text{Circumferential length } Lc1 = \sqrt{(X11-X21)^2 + (Y11-Y21)^2}$$

$$\text{Radial lengrh } Lr1 = \sqrt{(X31-X41)^2 + (Y31-Y41)^2}$$

$$\text{135 degrees direction length } L_{135}1 = \sqrt{(X51-X61)^2 + (Y51-Y61)^2}$$

Table 1 shows the results of a bead durability test.

Using a tyre test drum, test tyres were run for 5000 km under the following extraordinary condition, and the running distance L1 was measured until any visible damage appeared. In the table 1, the ratio of the running distance L1 to 5000 km is shown as the durability.

Tyre load: 9000 kg
Speed: 20 km/h
Inner pressure: 800 kPa

The test tyres had the following same structure except the contour in the region Y.

Tyre size: 11R22.5 (heavy duty radial tyre)
Rim size: 8.25X22.5
Internal tyre structure: Fig.1
Carcass: a single ply of steel cords (3X0.20+7X0.20) arranged at 90 degrees to the tyre equator
Belt: four plies of steel cords (3X0.20+6X0.35)
Belt cord angle: +67, +18, -18 and -18 (radially inside to outside)
Carcass height Ha: 128 mm

The specifications of the contours are also shown in Table 1.

Table 1

Tyre	Ref.1	Ex.1	Ex.2	Ex.3	Ex.4	Ex.5	Ex.6	Ex.7	Ex.8	Ref.2	Ref.9	Ref.10	Ref.11
Contour	Fig.11	Fig.2	Fig.2	Fig.2	Fig.2	Fig.2	Fig.2	Fig.2	Fig.2	Fig.12	Fig.2	Fig.2	Fig.2
Hp1 (mm)	105	105	105	105	105	105	105	105	105	105	105	105	105
R1 (mm)	R350	R350	R350	R350	R350	R350	R350	R350	R350	R120	R150	R200	R350
T1 (mm)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
T2 (mm)	--	7.5	7.5	7.5	7.5	18	14	6	5	--	4.5	6.5	7.5
Tm (mm)	--	13	11	9	7.5	17	15.5	11	11	--	8	8	11
T3 (mm)	--	24	24	24	21	21	21	24	24	--	24	24	24
Dm (mm)		3	5.5	7	8.5	5.5	5.5	5.5	5.5	--	4	4	5.5
h1 (mm)	--	40	40	40	40	75	65	30	20	--	40	40	40
h2 (mm)	--	55	55	55	55	20	30	65	75	--	55	55	55
h3 (mm)	--	30	30	30	30	10	15	40	50	--	30	30	30
h4 (mm)	--	25	25	25	25	10	15	25	25	--	25	25	25
hb (mm)	55	55	55	55	55	55	55	55	55	35	55	55	35
HP2 (mm)	--	65	65	65	65	30	40	75	85	--	65	65	65
Hpm (mm)	--	35	35	35	35	20	25	35	35	--	35	35	35
HP3 (mm)	--	10	10	10	10	10	10	10	10	--	10	10	10
Dm/Hp1	--	0.03	0.05	0.07	0.08	0.05	0.05	0.05	0.05	--	0.04	0.04	0.05
H2/Hp1	--	0.5	0.5	0.5	0.5	0.2	0.3	0.6	0.7	--	0.5	0.5	0.5
(T2/T1)/h1		0.05	0.05	0.05	0.05	0.07	0.06	0.06	0.07	--	0.03	0.05	0.05
(Tm/T2)/h3	--	0.06	0.05	0.04	0	0.09 Tm<T2	0.07	0.05	0.04	--	0.06	0.04	0.05
(T3/Tm)/h4	--	0.07	0.09	0.11	0.13	0.14	0.1	0.00	0.00	--	0.11	0.11	0.09
Durability	0.51	1	1	1	0.98	0.88	1	1	1	0.78	1	1	1
Damage	100	3	OK	OK	2	2	OK	OK	3	1(Z)	OK	OK	OK

*Note

1: A swelling was caused by carcass cord looseness in the bead portions. The position of the swelling is indicated in ( ). See the figure.

2: A swelling was caused by carcass cord looseness at the position Pm.

3: A carcass ply turnup edge looseness was found by a cut open inspection.

OK: No damage was found.

Ex.4: The dispersion of strain was less and the durability was lower than Ex.1-3 and 6-11 as the thickness T was constant (T2=Tm) from the point P2 to the point Pm, but better than Ref.1 and 2.

Ex.5: As the thickness T2 > the thickness Tm, the dispersion of strain was further decreased. The durability was lower than Ex.1-3 and 6-11 as the value h2/Hp1 was smaller, but higher than Ref.1 and 2.

Table 2 shows the results of additional tests. The test tyres were heavy-duty radial tyres having the following common data.

Tyre size: 11R22.5
Rim size: 8.25X22.5
Carcass: a single ply of steel cords (3X0.20+7X0.20)
Carcass cord angle: 90 degrees to the tyre equator
Carcass cords count: 40/5cm
Belt: four plies of steel cords (3X0.20+6X0.35)
Belt cord angle: +67, +18, -18 and -18
(radially inside to outside)
Belt cord count: 26/5cm

The tests included a durability test similar to the above-mentioned test, crack test, principal strain test, and tyre weight test.

* Durability Test

Using a tyre test drum, test tyres were run for 10000 km under the following extraordinary condition, and the running distance Ll until any visible damage appears was measured. In the table 2, the ratio of the running distance Ll to 10000 km is shown as the durability.

Tyre load: 9000 kg
Speed: 20 km/h
Inner pressure: 1000 kPa

* Crack Resistance Test

The test tyres inflated to the standard pressure of 800 kPa was set in an ozone chamber (Ozone: 40 ppm, Temperature: 40 deg. C), and the time until cracks occurred in the region Y was measured. In Table 2, the time is indicated by an index based on that the prior art tyre is 100. The larger the index, the better the resistance.

* Principal Strain Test

The principal strain was obtained as explained above, and examined whether a remarkable peak appeared or not, and the maximum principal strain C was measured.

* Tyre weight test

The tyre weight was measured. In the table 2, the tyre weight is indicated by an index based on that the prior art tyre is 100. The smaller index is better.

Table 2

Tyre	Ex. B1	Ex. B2	Ex. B3	Ex. B4	Ex. B5	Ex. B6	Ex. B7	Ex. B8	Ex. B9	Ref. B1	Ref.B2	Prior
L (mm)	8.3	16.3	33	49.5	66	82.5	33	49.5	66	3.3	99	0
CW (mm)	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5
L/CW	0.5	1	2	3	4	5	2	3	4	0.2	6	0
Bead Contour	Fig.6	Fig 6	Fig.6	Fig.6	Fig.6	Fig.6	Fig.1	Fig.1	Fig. 1	Fig.6	Fig.6	Fig.7
Max strain (%)	4.5	2	2	2	2	2	2	2	2	4.5	2	8.5

Table 2 (continued)

Tyre	Ex. B1	Ex. B2	Ex. B3	Ex. B4	Ex. B5	Ex. B6	Ex. B7	Ex. B8	Ex. B9	Ref. B1	Ref.B2	Prior
Peak	none	none	none	none	none	none	none	none	none	none	none	none
Crack	130	300	300	300	300	300	300	300	300	130	300	100
Durability	115	135	180	200	200	200	180	2000	2000	85	200	100
Tyre weight	80	82	85	90	95	99	83	87	92	79	100	100

In the tyres according to the invention, the principal strain C was decreased under 5.0% and had no peak in the region Y, and the resistance to cracks was greatly improved. In particular, the tyres Ex.B3, B4, B5, B7, B8 and B9 in which the parallel part length L was in the range of from 2.0 to 4.0 times the bead core maximum-section-width CW had a good bead durability, and the performance was excellent in total balance. Additionally, the tyres Ex. B7, B8 and B9 provided with the above-mentioned contours S1 and S2 could be effectively decreased in the tyre weight.

Claims

1. A pneumatic tyre comprising a tread portion (2), a pair of sidewall portions (3), a pair of bead portions (4) each with a bead core (5) therein, a carcass (6) extending between the bead portions (4) through the tread portion (2) and sidewall portions (3) and turned up around the bead cores (5) in the bead portions (E1) from the inside to the outside of the tyre to form a pair of turnup portions (6B) and a main portion (6A) therebetween, characterise din that in a standard condition in which the tyre is mounted on a standard rim and inflated to a standard pressure but loaded with no tyre load, the outer surface of the tyre is provided with a mid-lower sidewall contour S1 and a lower sidewall contour S2, the mid-lower sidewall contour S1 extending radially inwardly from the maximum cross sectional width point P1 of the tyre to a point P2 along a circular arc line E1 having a single radius R1 and the centre on an axial line passing the maximum cross sectional width point P1, the lower sidewall contour S2 extending on the axially inside of the circular arc line E1 from the point P2 to a radially inner point P3, and the thickness T measured from the outer surface of the tyre to the main portion of the carcass (6A) gradually increases from the point P1 to the point P2.

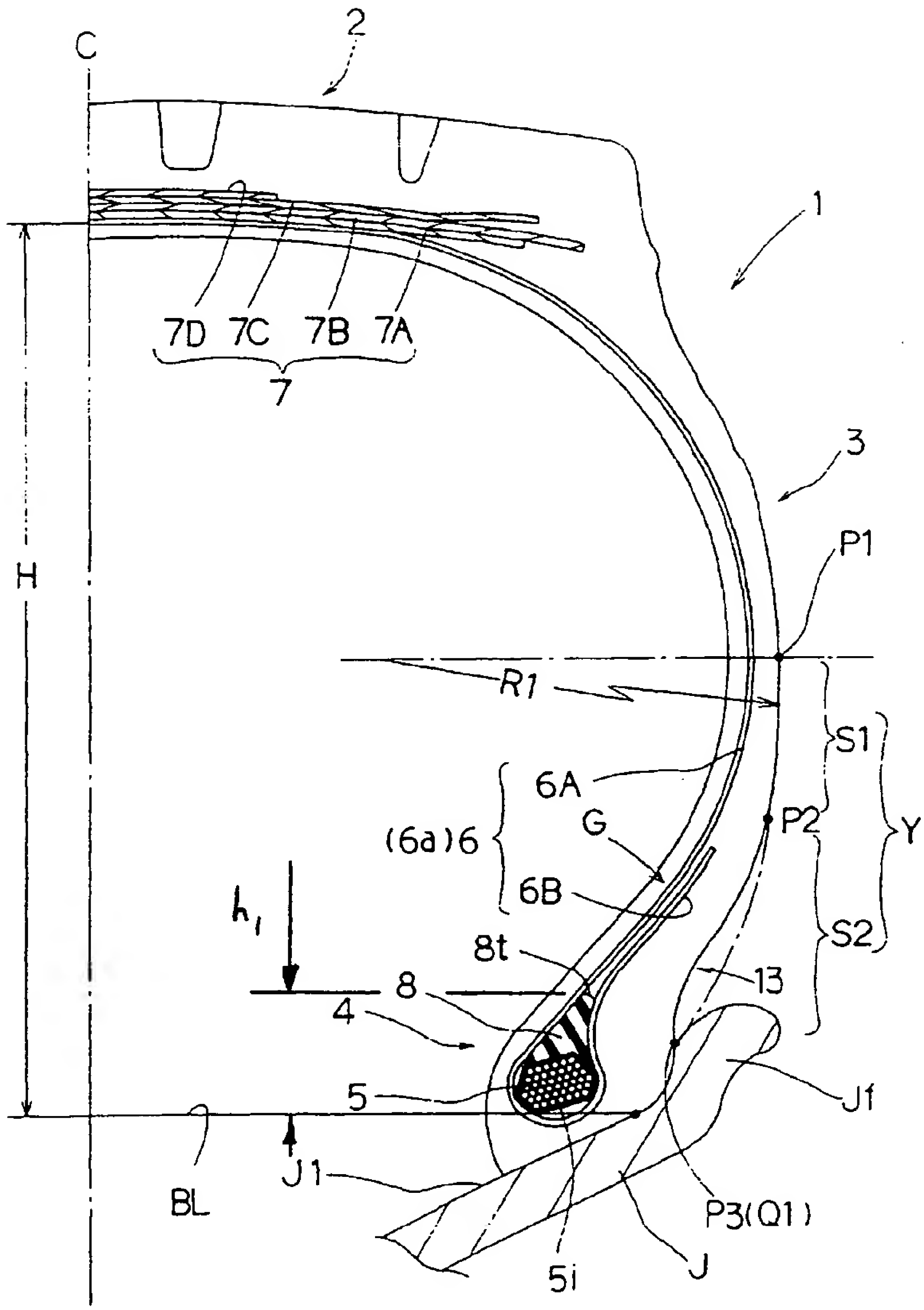
2. A pneumatic tyre according to claim 1, characterised in that the maximum depression Dm of the lower sidewall contour S2 from the circular arc line E1 is in the range of from 0.03 to 0.18 times the radial height Hp1 of the maximum width point P1, and the radial height difference h2 between the points P2 and P3 is in the range of from 0.2 to 0.7 times the height Hp1.

3. A pneumatic tyre according to claim 1 or 2, characterised in that wherein the thickness T is gradually increased from the point P2 to a point Pm at which the depression D of the lower sidewall contour S2 from the circular arc line E1 becomes maximum, and the maximum depression Dm at the point Pm is in the range of from 0.03 to 0.18 times the radial height Hp1 of the maximum width point P1, and (T2/T1)/h1 is not less than 0.03 wherein 1 is the thickness at the point P1, T2 is the thickness at the point P2, and h1 is the radial height difference between the points P1 and P2.

4. A pneumatic tyre according to any of claims 1 to 3, characterised in that the bead portions (4) are provided between the carcass main portion (6A) and each turnup portion (6B) with a bead apex (8) made of hard rubber tapering radially outwardly to the radially outer end thereof, the turnup portion (6B) extends radially outwardly beyond the radially outer end (8t) of the bead apex to form a parallel part, the parallel part extending radially outwardly from the radially outer end (8t) of the bead apex (8) substantially parallel to the carcass main portion (6A), and the length L of the parallel part is in the range of from 0.5 to 5.0 times the maximum-section-width CW of the bead core (5).

5. A pneumatic tyre according to claim 4, characterised in that the length L of the parallel part is 2.0 to 4.0 times the maximum-section-width CW of the bead core.

Fig.1



C
2
1
7D
7C
7B
7A
7
3
H
P1
R1
S1
6A
P2
Y
G
(6a)6
6B
h_1
S2
8t
13
8
4
5
J1
BL
J1
P3(Q1)
5i
J

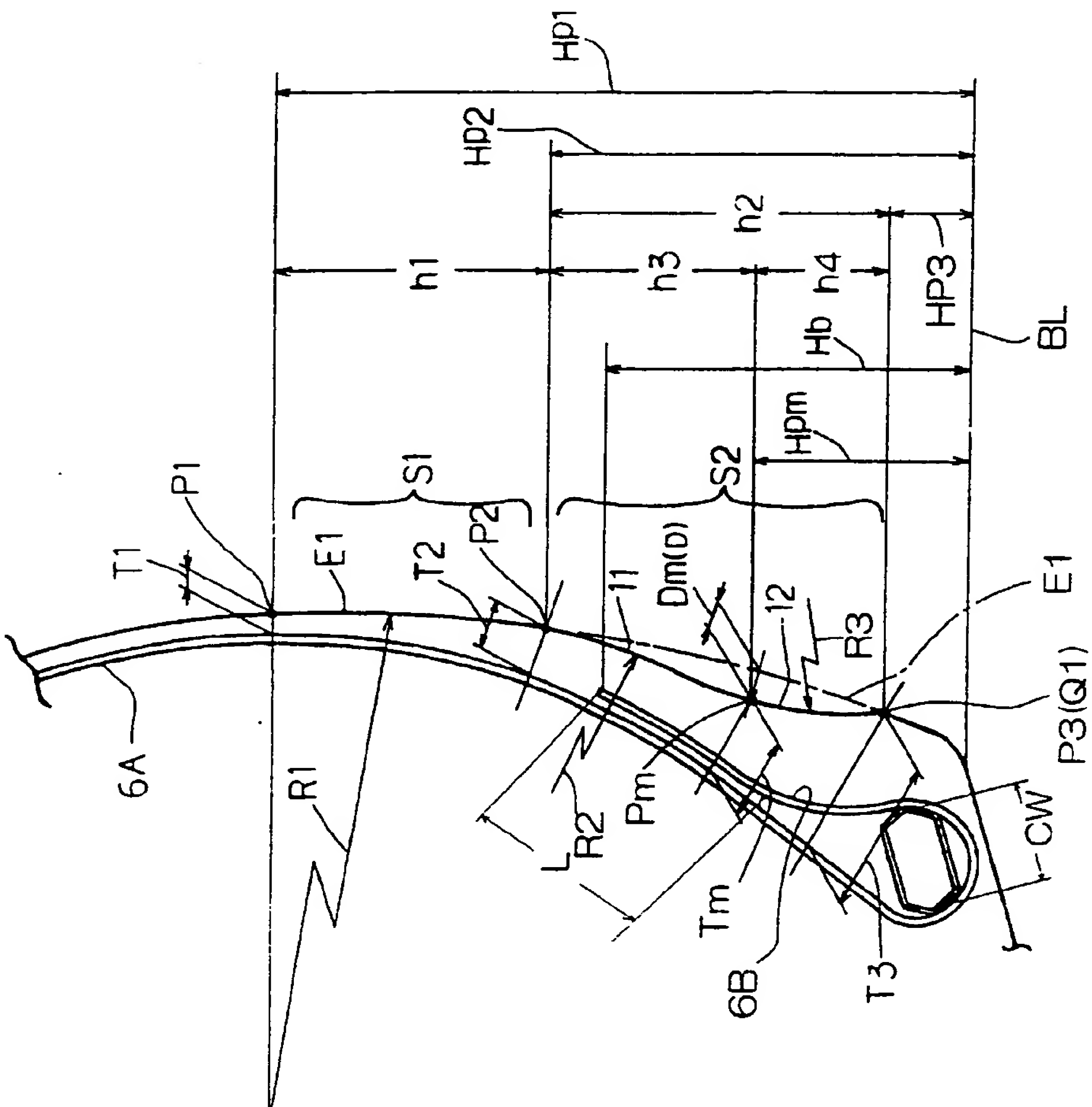

Hp1
HP2
h1
h2
h3
h4
HP3
Hb
BL
Hpm
S1
S2
P1
T1
E1
T2
P2
l1
Dm(D)
l2
R3
E1
P3(Q1)
6A
R1
R2
Pm
L
Tm
6B
T3
CW

Fig.2

Fig.3

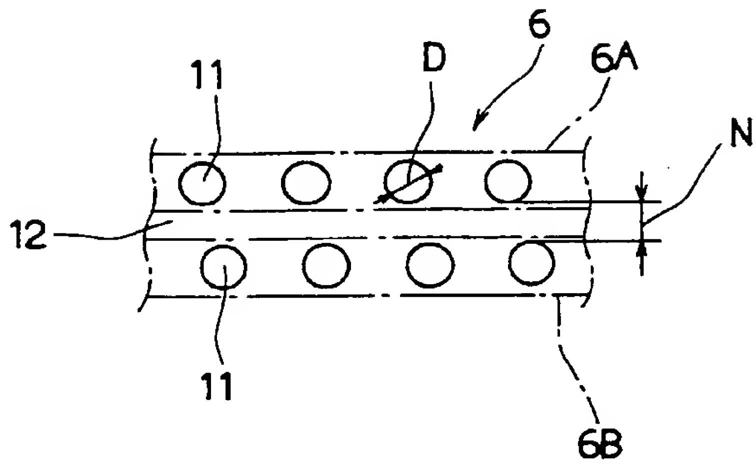


Fig.4(A)

Fig.4(B)

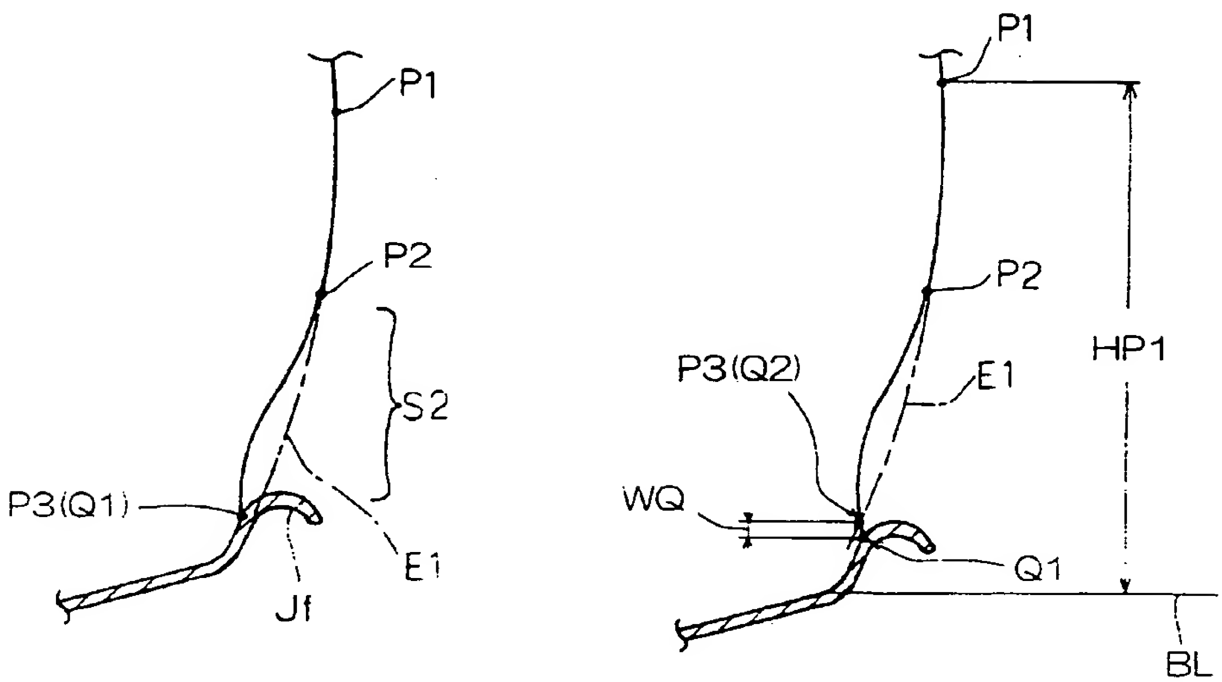


Fig.5

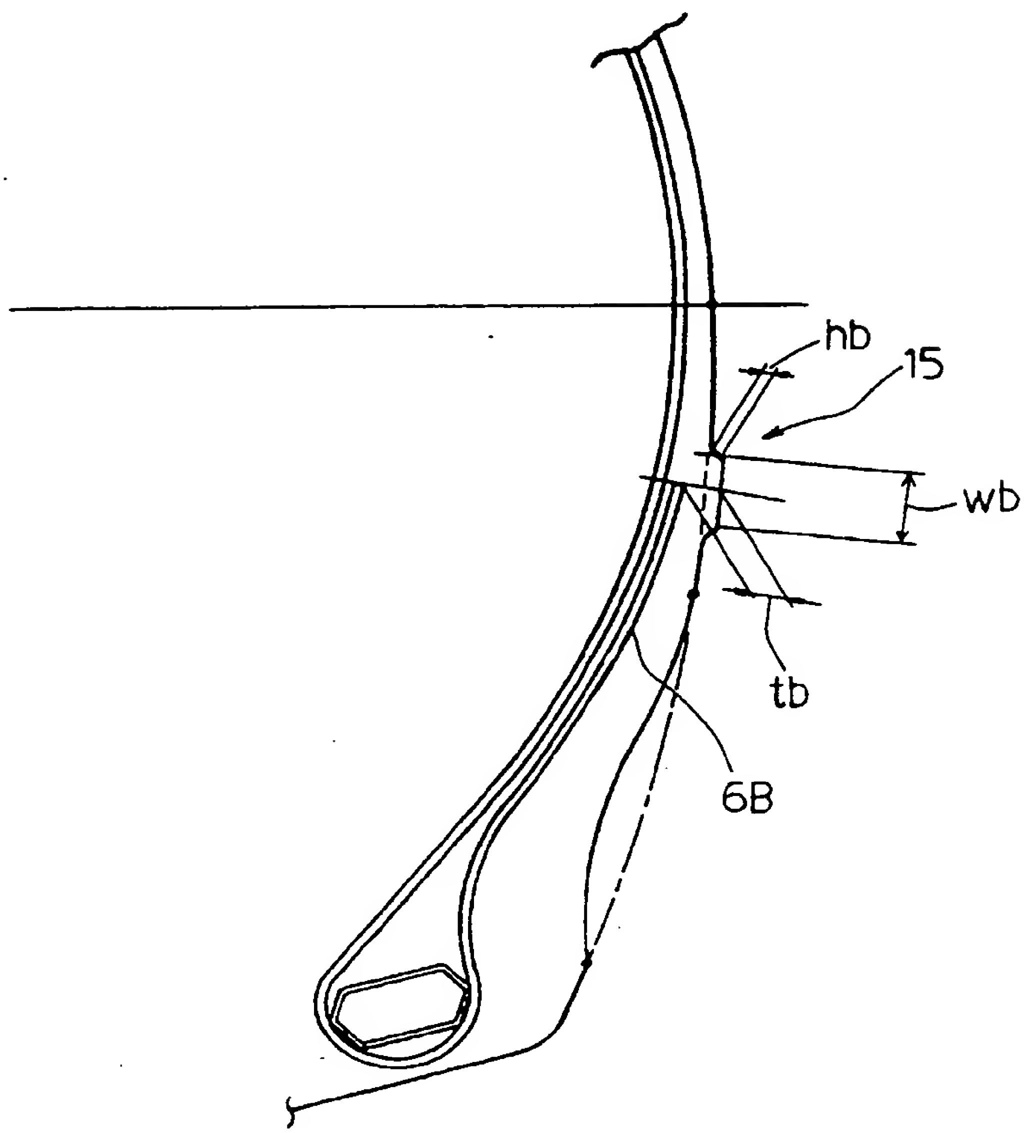


Fig.6

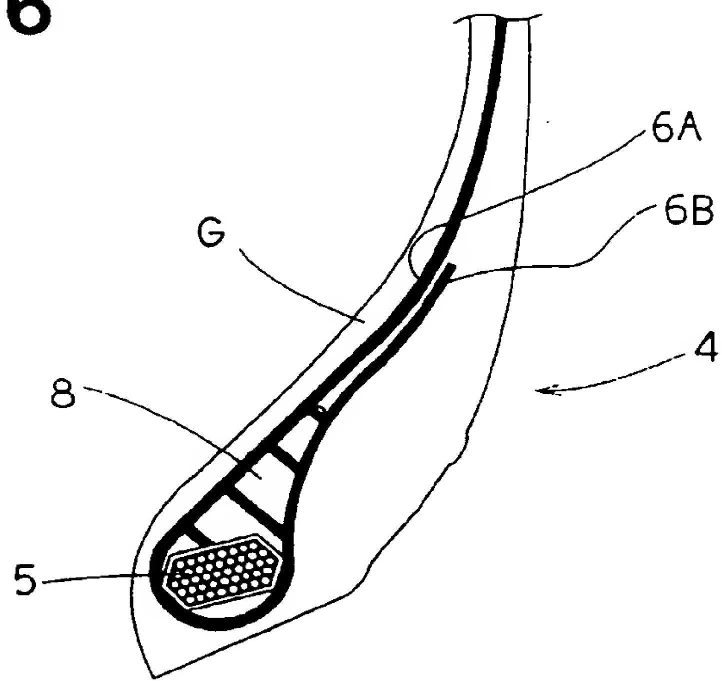


Fig.7

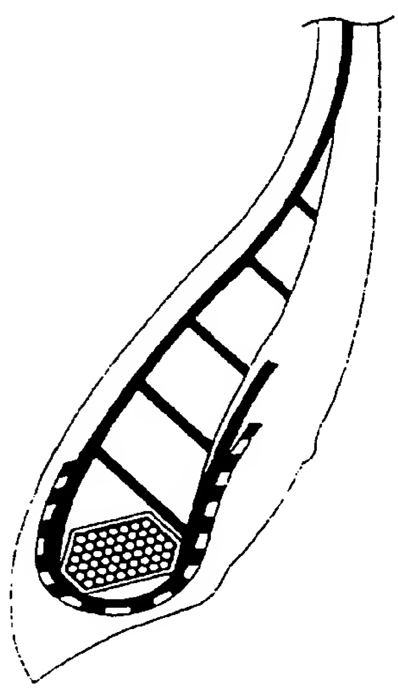


Fig.8

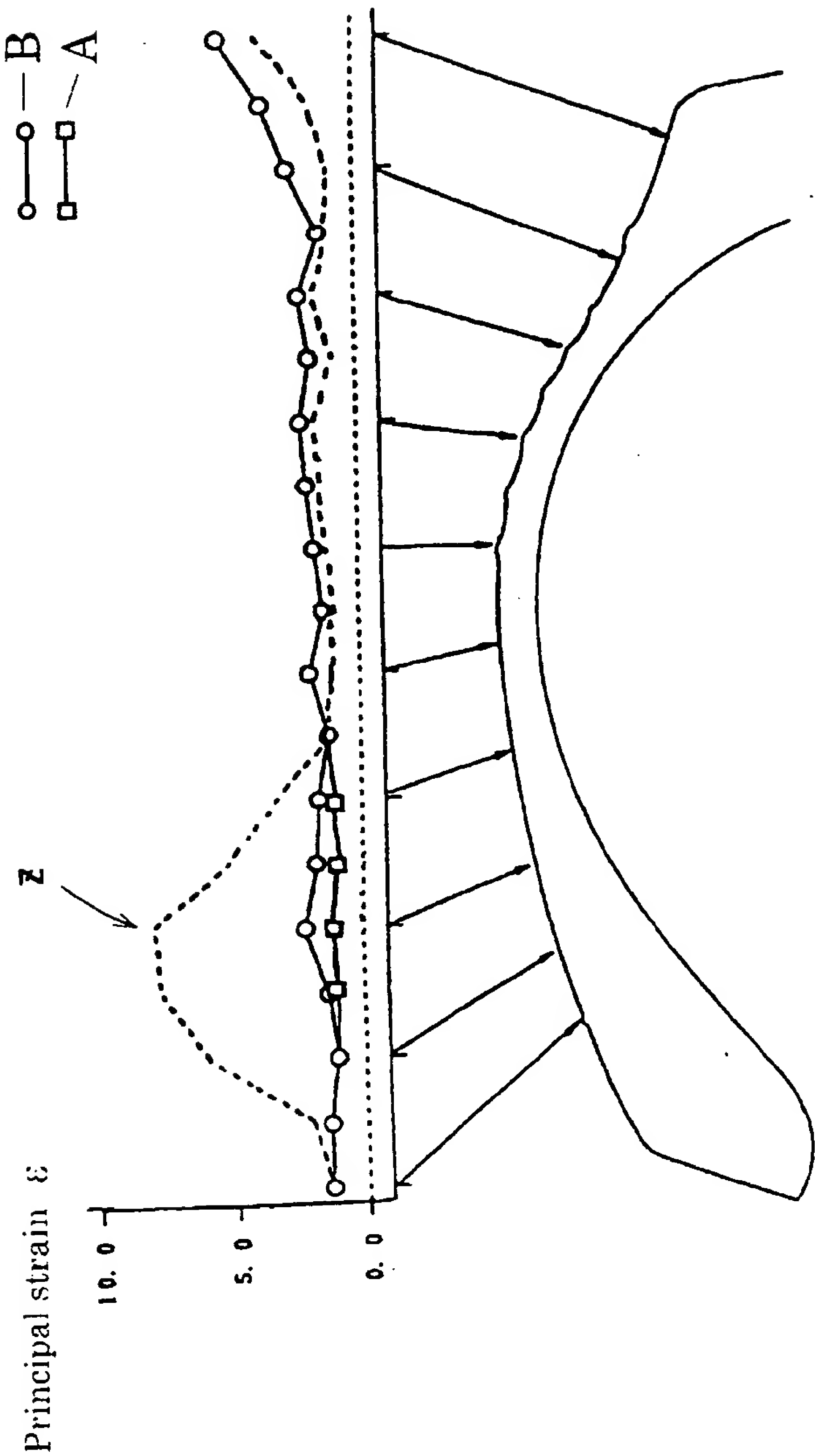


Fig.9

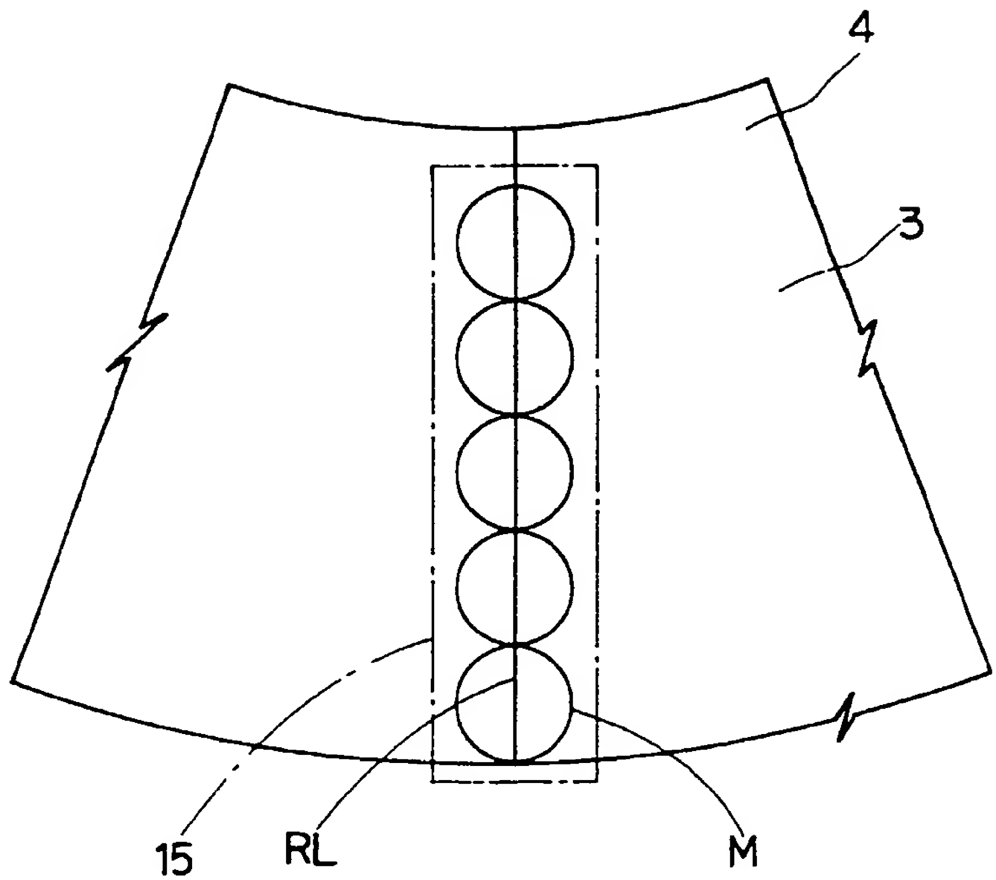
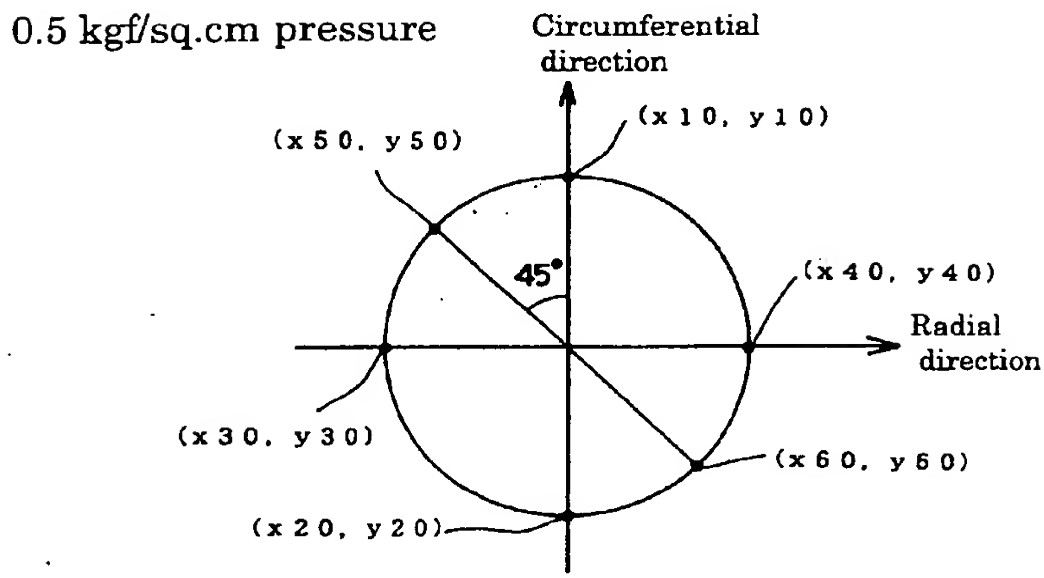


Fig.10


0.5 kgf/sq.cm pressure
Circumferential direction
(x 1 0, y 1 0)
(x 5 0, y 5 0)
45°
(x 4 0, y 4 0)
Radial direction
(x 3 0, y 3 0)
(x 6 0, y 6 0)
(x 2 0, y 2 0)

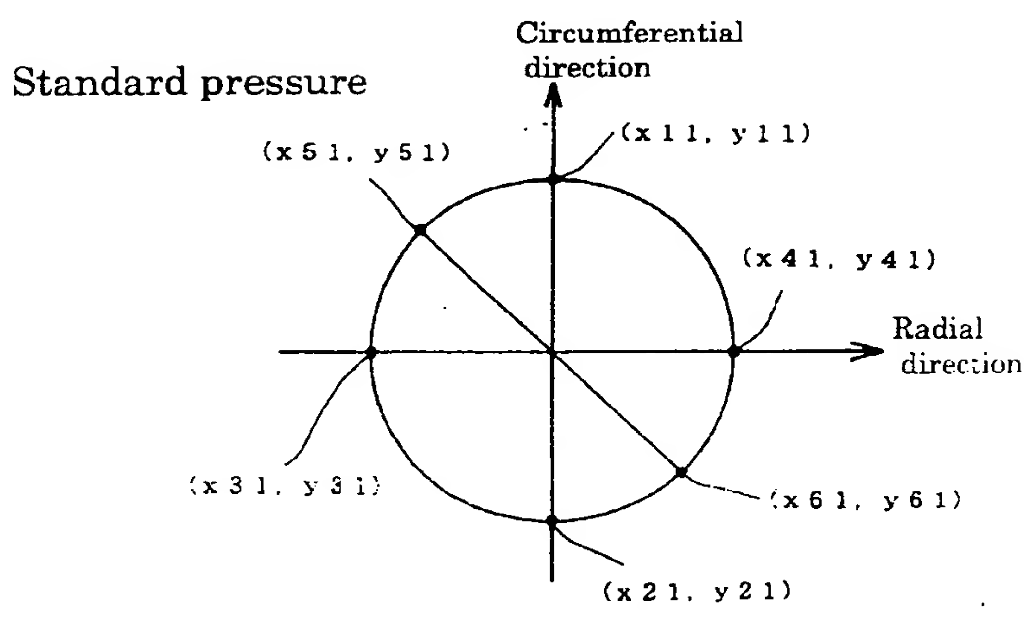

Standard pressure
Circumferential direction
(x 1 1, y 1 1)
(x 5 1, y 5 1)
(x 4 1, y 4 1)
Radial direction
(x 3 1, y 3 1)
(x 6 1, y 6 1)
(x 2 1, y 2 1)

Fig.11

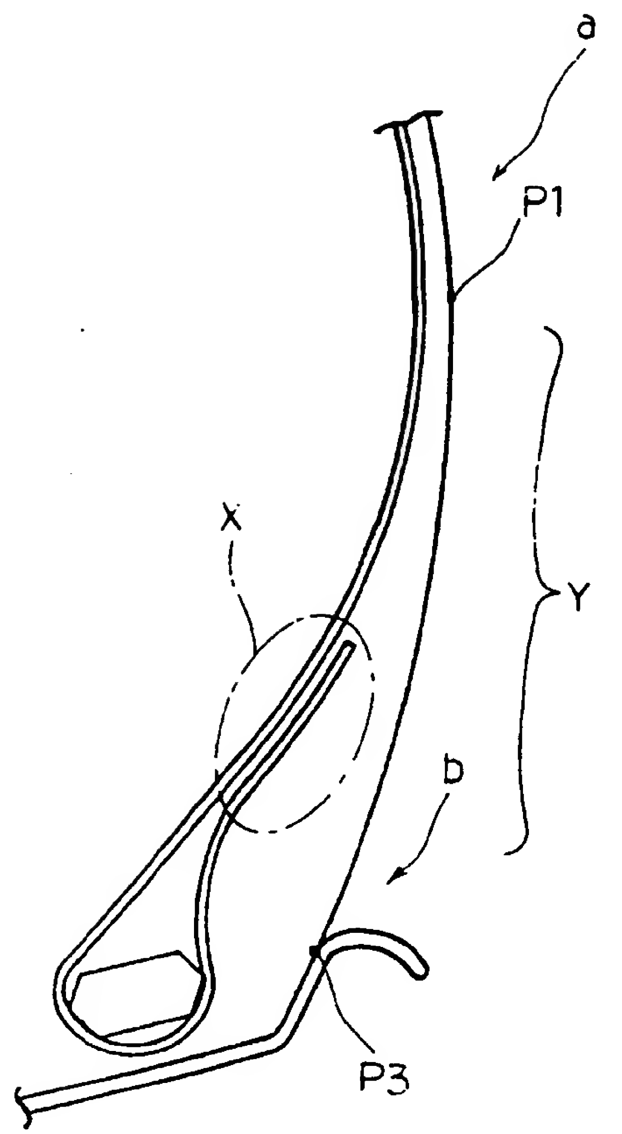


Fig.12